

DESIGN OF TWO-WIRE SUBSCRIBER LOOP AND
PABX TRUNK PLANT

- PURPOSE: This Addendum changes Table I of TELCM 424, Issue No. 3, dated April 1973, to correct an error.
- DELETION: Delete 16.6 in Maximum Circuit Length, MI. column on line of 24-D-66 60.8 KF.
- ADDITION: Insert 11.4 in Maximum Circuit Length, MI. column on line of 24-D-66 60.8 KF.

DESIGN OF TWO-WIRE SUBSCRIBER LOOP AND
PABX TRUNK PLANT

CONTENTS

1. GENERAL
2. GENERAL TRANSMISSION REQUIREMENTS
3. CABLE GAUGE SELECTION
4. CENTRAL OFFICE LOOP LIMITS
5. MAXIMUM OUTSIDE PLANT LOOP RESISTANCE
6. BOOSTER POWER SUPPLY
7. VOICE FREQUENCY REPEATERS
8. BRIDGED TAP ISOLATORS
9. MEANS FOR MEETING END-SECTION REQUIREMENTS
10. STAKING AND LOAD SPACING REQUIREMENTS
11. CENTRAL OFFICE BRIDGING OF PAIRS
12. TELEPHONE SETS
13. NOISE CONSIDERATIONS
14. SUBSCRIBER OR STATION CARRIER
15. ELECTRONIC SUBSCRIBER LINE SWITCHING SYSTEMS
16. WHEN TRANSMISSION COMPUTATIONS NEED BE MADE

TABLES I AND II

CHARTS I - III

FIGURES 1 - 4

1. GENERAL

1.1 This section provides REA borrowers, consulting engineers, contractors and other interested parties with technical information for use in the design and construction of REA borrowers' telephone systems. The procedure used to lay out subscriber loop plant and PABX trunks is discussed.

NOTE: In view of increasing movement toward universal adoption of the Metric System, the following conversion factors are provided:

<u>To Convert</u>	<u>Into</u>	<u>Multiply By</u>	<u>Conversely, Multiply By</u>
Inches	Centimeters	2.540	0.3937
Feet	Centimeters	30.48	3.281×10^{-2}
Kilofeet	Kilometers	0.305	0.3281
Miles (Statute)	Kilometers	1.609	0.6214

1.2 This revision replaces REA TE&CM 424, Issue No. 2, dated October 1965 and reflects changes in design objectives and increased utilization of finer gauge cables with electronic transmission and signaling devices. Significant changes in design objectives include a reduction in the permissible 1000 Hz loss, revision of the voice frequency response objectives and improvement in the idle circuit noise requirements (see REA TE&CM 415, Issue No. 4).

1.3 Design emphasis centers on the following factors:

- (a) Central office signaling limits of 1700 ohms outside plant loop resistance without the telephone set.
- (b) 24 and 22 gauge cable for backbone plant, 0.083 $\mu\text{F}/\text{mi}$ average mutual capacitance.
- (c) Limited use of 26 gauge cable in high density areas, 0.083 $\mu\text{F}/\text{mi}$ mutual capacitance, where no future extension beyond the 26 gauge limit or multi-channel carrier application is anticipated.
- (d) De-emphasis of 19 gauge multi-pair cable.
- (e) Maximum loading of loops.
- (f) Use of D-66 loading.
- (g) Central office and/or field mounted voice frequency repeaters on all loops over 1700 ohms outside plant resistance.
- (h) Utilization of Bridged Tap Isolators (BTI's) and low capacitance buried distribution wire.
- (i) Use of loop extenders or long line adapters with additional 48-volt booster power supply on all loops over 1700 ohms outside plant loop resistance.
- (j) Elimination of transmission computations in most cases.
- (k) Reduction in the number of central offices in a given area due to increased signaling and transmission limits.

1.4 Application of all design procedures in this section will result in satisfactory transmission to all subscribers. Where finer gauge cables are used, this will normally also result in the most economical design.

1.5 The design-by-loss method is used in this section to compute the 1000 Hz loss to the subscriber. This method is based on the

actual transmission loss in the loop in the same manner as transmission computations are made for trunk circuits. It is not only possible to know the actual loss of the loop in the design but also to verify its performance by measurement. This can be accomplished by one man initially, and on a routine basis thereafter. It can also be used when transmission difficulties are being experienced or when circuit rearrangements are being made. Equipment which can be used by one man to verify the design-by-loss is a portable loop checker for connection to subscribers stations in conjunction with a reference tone generator and quiet termination in the central office which can be "dialed up" from any subscriber loop. When a multi-frequency generator is available in the office, the circuit frequency response can also be measured. Some loop checkers now available are also capable of measuring dc loop current, circuit noise (noise metallic) and power influence (noise-to-ground), therefore, a thorough transmission test can be quickly made on nearly all types of loops.

1.6 Consistent application of the design procedures in this section assures that when loop checker equipment is used, applicable requirements can be verified.

2. GENERAL TRANSMISSION REQUIREMENTS

2.1 Transmission Objectives

2.11 Loss to the farthest subscriber in any loop should not exceed 8 dB at 1000 Hz exclusive of the loss in the central office. All other loops are designed to have better transmission than the limiting loop (see Figure 1).

2.12 Loss to a PABX location should not exceed 5 dB at 1000 Hz exclusive of the loss in the central office (see Figure 2A).

2.121 Loss to the farthest PABX station should not exceed 8 dB at 1000 Hz exclusive of the loss in the central office and including a 0.5 dB loss in the PABX. This is the sum of the PABX trunk, PABX switching loss and PABX station loop losses (see Figure 2B).

2.2 Noise Objective

2.21 Noise objective for subscriber loops should be 20 dBrn-C or less circuit noise (noise metallic) as measured at the line terminals of telephone sets at the subscriber location using a Noise Measuring Set or portable loop checker in conjunction with a dialed up "quiet termination" at the central office end of the circuit.

2.3 Non-Loaded Loops

2.31 Subscriber loops in cable which are 18 kf or less in length, including all bridged taps, need not be loaded except as noted below.

2.311 Subscriber loops entirely in 26 gauge cable should not exceed 15 kf including all bridged tape.

2.32 PABX trunks in cable which are 11 kf or less in length need not be loaded except as noted below.

2.321 PABX trunks entirely in 26 gauge non-loaded cable should not exceed 9 kf.

2.4 Bridged Tap Requirements - Non-Loaded Loops

2.41 Non-loaded loops should have no more than 6000 feet of bridged tap whether it be in one bridged tap or the sum of several taps, as viewed from any subscriber location on the loop. Bridged tap lengths are included in total cable length for determining when loading is required (see Figure 3).

2.42 PABX trunks should have no bridged taps.

2.5 Loops Which Require Loading

2.51 Loops where cable length, including all unisolated bridged taps, extend 18 kf or more from the central office regardless of gauge should be loaded.

2.511 Loops which are entirely 26 gauge cable, including all unisolated bridged taps, should not be extended beyond 15 kf from the central office and, therefore, do not require loading.

2.512 Special transmission considerations may require loading of loops with a length shorter than 18 kf. This would improve the return loss of the loop as well as its frequency response. Two, or in some cases, only one loading point will help improve the transmission characteristics.

2.52 PABX trunks where cable length extends 11 kf or more from the central office regardless of gauge should be loaded for their entire length.

2.521 Cable length of PABX trunks which are entirely 26 gauge cable should not be extended beyond 9 kf from the central office and, therefore, do not require loading.

2.6 Definition of Loaded Loop Subscriber End-Section

2.61 A subscriber end-section is defined as the total length of exchange cable (0.083 microfarads per mile average mutual capacitance) extending beyond the last loading coil on the subscriber end of the facility.

(NOTE: Unless specified otherwise, end-section always refers to subscriber end-section.)

2.62 An end-section in D-66 loaded cable is defined as "long end-section" when: (1) it's length is between 6.5 and 12 kf total after the last loading point including all unisolated bridged taps with exchange cable, or (2) it does not exceed 24 kf with low capacitance distribution wire (0.045 microfarads per mile average mutual capacitance).

2.63 An end-section in D66 loaded cable is defined as "short end-section" when it is between 2 and 6.5 kf in length.

2.64 Loaded loops designed for one-party service and PABX trunks should have "short end-sections" only. They should have all the loading coils which can be properly placed in that length of cable with no bridged taps.

2.7 Loaded Subscriber Loop End-Section - "Long End-Section"

2.71 Length of the subscriber end-section should be as short as practicable consistent with maintaining adequate line fills.

2.72 Maximum subscriber end-section length for D-66 loading should not exceed 12 kf total including all unisolated bridged taps. Maximum end-section for H88 loading should not exceed 9 kf including all unisolated bridged taps.

2.8 Loaded Subscriber Loop End-Section - "Short End-Section"

2.81 Subscriber end-section in a short end-section loaded loop can be between 2000 and 6500 feet.

2.82 When subscriber end-sections in a short end-section loaded loop are less than 2000 feet in length, the last loading coil should be removed.

2.83 Maximum loading should be used in loaded loops intended for one-party service because end-section requirements are no longer controlling.

2.9 Loading Systems

2.91 For new construction or essentially new construction, D-66 loading should be used.

2.92 When upgrading existing plant, consider D-66 loading. If not practicable, consider extending with the existing loading system in use and apply the design procedure in Table II for H-88 loading. Continued use of H-88 loading should be weighed against its transmission limitations.

3. CABLE GAUGE SELECTION

- 3.1 Economic considerations must be weighed in determining the proper cable gauge. This is especially important when considering installation of fine gauge cable. Additional maintenance costs which might result should be compared with apparent first cost savings. Also, consider the probability that some of the facilities may later be used for carrier or other electronic equipment when selecting cable gauges. Consider finer gauges where cables are large and coarser gauge where cables have very few pairs. This can facilitate future circuit expansion by carrier, if necessary.
- 3.12 In weighing first cost savings against increased maintenance expense, special consideration should be given to lightning damage. Calculations show 26 gauge cable to be about four times more likely to be damaged by lightning than 22 gauge cable and about two times more likely than 24 gauge cable. Increased lightning damage to 26 gauge as compared to other gauges should be considered with all other factors such as annual charges, frequency of service outages, etc. Large pair size 26 gauge cables (more than 200 pairs) close to the central office are less likely to be damaged by lightning than are smaller pair sizes. In urban areas buildings and other utility lines provide considerable shielding against lightning that is not available in rural areas.
- 3.2 Consider the economics of selecting 26 gauge where the longest circuit lengths of a route do not exceed 2.8 miles from the central office. Twenty-six gauge cable loops should not be loaded.
- 3.21 Consider the selection of 24 gauge for circuit lengths up to 10.7 miles from the central office for loops with "long" or "short" subscriber end-sections.
- 3.22 For distances longer than 10 to 12 miles from the central office, consider the selection of 22 gauge or 22 and 24 gauge combinations.
- 3.23 For 24 or 22 uniform gauge plant, lay out the transmission design in accordance with Table I or II. No transmission computations need be made.
- 3.24 For mixed 24 and 22 gauge plant, lay out the transmission design in accordance with Chart III. No transmission computations need be made.
- 3.25 Nineteen gauge cable should not be used unless the above procedures are not found economical. In general, use 19 gauge in one- and three-pair sizes only for subscriber distribution at the end-sections or for long subscriber or station carrier routes.

3.26 Nineteen gauge multi-pair cable should be used only for circuit lengths exceeding 4300 ohms with 22 gauge cable. Compute the transmission in accordance with REA TE&CM 426, "Subscriber Loop Computations - Design-by-Loss Method."

3.27 When upgrading existing plant different gauges or more than two of the gauges shown in Tables I and II and Chart III will probably be retained. The recommended maximum dc loop resistance values in Charts I and II still apply for all gauge mixtures. Use the information in REA TE&CM 426 to compute the dc loop resistance.

3.3 Separate Cables

3.31 Consideration should be given to the economics of providing separate cables of different gauges. Subscribers nearer the central office might be served via finer gauge cable without the higher cost penalty of coarser gauge cable needed for longer subscriber loops. The coarse gauge cable can be utilized for the future extension of subscriber carrier.

4. CENTRAL OFFICE LIMITS

4.1 During past years, step-by-step central offices of some manufacturers have been arranged to operate properly (without a long line adapter (LLA) or loop extender) with up to 1700 ohms of outside plant dc loop resistance with buried plant construction. All common control type offices listed by REA meet this requirement. With aerial cable construction, these offices should operate properly up to 1500 ohms outside plant loop resistance.

4.2 Older central offices can sometimes be economically modified to meet the signaling limits of paragraph 4.1 above. For further information, refer to the applicable 300 series sections of the Engineering Manual.

4.21 Values of outside plant dc loop resistance referred to in paragraph 4.1 above include the resistance of all plant components but do not include the central office battery feed dc resistance and the telephone set resistance which are normally about 400 and 200 ohms, respectively.

4.3 Loops longer than 1700 ohms for buried plant and 1500 ohms for aerial cable plant referred to in paragraph 4.1 above require that a central office mounted long line adapter or loop extender unit be used, either in a regular design or in a common mode arrangement (see TE&CM 429). In Common Mode arrangements a minimum of voice frequency repeaters and Long Line Adapters are connected in a non-dedicated manner to serve a large number of loops requiring long loop devices.

4.31 A long line adapter unit in a 48-volt central office supplemented with a 24 or 48 volt booster power supply (paragraph 6 below) operates properly up to 3000 and 4300 ohms outside plant loop resistance, respectively.

4.32 A loop extender unit in a 48 volt central office (described in TE&CM 332) operates properly up to 4300 ohms total outside plant resistance.

5. MAXIMUM OUTSIDE PLANT LOOP RESISTANCE

5.1 Outside plant dc loop resistance of the longest loop equipped with a long line adapter or loop extender unit should not exceed 4300 ohms.

6. BOOSTER POWER SUPPLY

6.1 Booster power supply should be used on all buried plant loops over 1700 ohms and aerial cable loops over 1500 ohms outside plant dc loop resistance when a long line adapter is used. No booster power supply is required when a loop extender is used.

6.2 Use 24 volt booster with loops up to 3000 ohms maximum outside plant dc loop resistance.

6.3 Use 48 volt booster with loops up to 4300 ohms maximum outside plant dc loop resistance.

6.4 In all cases a 48 volt booster may be used in lieu of a 24 volt booster but not the reverse.

7. VOICE FREQUENCY REPEATERS

7.1 No voice frequency repeaters should be used for loaded loops up to 1300 ohms outside plant dc loop resistance with 2 to 12 kf end-sections as shown in Chart I.

7.2 For loaded loop with end-sections of 2 to 6.5 kf no voice frequency repeaters should be used with up to 1700 ohms outside plant dc loop resistance as shown in Chart I.

7.21 Loaded loops with end-sections in excess of 6.5 kf to approximately 12 kf may be utilized in the zone between 1300 and 1700 ohms. Such loops will provide for efficient distribution of party line service and should be designed on an individual basis.

7.3 Repeaters with Manual Gain Control

7.31 For loaded loops with 2 to 12 kf end-sections, central office mounted voice frequency repeaters set for 6.5 dB net gain should

be used between 1700 and 3000 ohms outside plant dc loop resistance. Refer to Chart I.

7.32 Common Mode Operation: For loaded loops beyond 3000 ohms outside plant dc loop resistance, augment the central office mounted voice frequency repeaters, set for 6.5 dB net gain, with a field mounted repeater set for 4.5 dB net gain. End-section limits in paragraphs 7.331, 7.332 and 7.333 apply.

7.33 Non-Common Mode Operation

7.331 Field mounted voice frequency repeaters set for 11 dB net gain should be used on loaded loops with end-sections of 2 to 12 kf between 3000 and 3800 ohms. Refer to Chart I.

7.332 Field mounted voice frequency repeaters set for 11 dB net gain should be used on loaded loops with end-sections of 2 to 6.5 kf between 3800 and 4300 ohms. Refer to Chart I.

7.333 Loaded loops with end-sections in excess of 6.5 kf to approximately 12 kf may be utilized in the zone between 3800 and 4300 ohms. Such loops will provide for efficient distribution of party line service and should be designed on an individual basis.

7.4 Repeaters with Automatic Gain Control

7.41 Voice frequency repeaters with automatic gain control may be used at this time with all loaded loops in Common Mode arrangements. When dc loop resistance of the outside plant is less than 1400 ohms, less than 1 dB net gain is provided. Between approximately 1400 ohms and 2200 ohms, 3.5 dB net gain is provided and 6.5 dB net gain beyond approximately 2200 ohms. Maximum benefits of the repeaters with automatic gain control is expected to be in Common Mode Operation. Refer to Chart II.

7.42 End-section limits of paragraphs 7.32, 7.331, 7.332 and 7.333 apply to repeaters with automatic gain control.

8. BRIDGED TAP ISOLATORS (BTI'S)

8.1 Consideration should not be given to the use of bridged tap isolators for controlling subscriber end sections until all other means have failed. Assignments should be checked to ascertain that subscribers have been grouped as close to each other as practicable. All bridged taps not in use should first be eliminated.

8.2 Refer to REA TE&CM 428, "Application and Use of Bridged Tap Isolators for Subscriber Loops," for detailed application guides.

9. MEANS FOR MEETING END-SECTION REQUIREMENTS

9.1 Proper Subscriber Assignment

9.11 Station numbers and line assignments should be considered at the time the plant layout is made up and then reviewed carefully at the construction stage by the design engineer.

9.2 Disposition of Unused Cable Pairs

9.21 Portions of cable pairs extending beyond the point of the last subscriber's connection on the lead should be cut dead. For protection considerations, the portion of the pair cut dead should be left floating at both ends. That is, the dead portion of the pair should not be grounded at either end.

9.3 Low capacitance buried distribution wires may be used to electrically shorten the end section.

9.4 Bridged Tap Isolators to maintain proper end-section should be used only after all other possibilities have been eliminated.

10. STAKING AND LOAD SPACING CONSIDERATIONS

10.1 Staking and Construction

10.11 Staking of plant for each major lead should start from the central office and proceed in the direction of the subscribers, never in the opposite direction. Staking of plant extensions should start from the office end and proceed toward the subscribers. Load spacing for plant extensions should be based on spacing along the major lead to the point of departure as a continuation of that design. The main objective during staking and construction periods is to meet the office end-section and load spacing requirements and, where terrain and other factors are favorable, to try to improve them.

10.12 Staking of each section as close to the nominal 4500 feet (D) and 6000 feet (H) is desirable and will permit full benefits to be derived from the application of electronic equipment. An important consideration is that within the average spacing, each loading section be staked to look as much like the other loading sections as possible. This is especially true for the four or five sections adjacent to electronic equipment such as office and field mounted repeaters.

10.2 Office End-Section Length

10.21 Office end-section should be one-half (0.5) the length of the normal full section. Where it is not possible or practical to meet this objective, an end-section length within 0.4 to 0.6 of the normal full section can be considered. Choice of the 0.4 length is preferable to the 0.6 end-section because of the through circuits.

10.3 Load Spacing Requirements (D-66)

10.31 As built plant, including main cable length, lateral cable distance to and from pedestals, pedestal height, pedestal

loop-around and all other incidental lengths should meet the following spacing requirements:

10.32 Deviation of the average spacing from the standard spacing should be within ± 3 percent.

10.33 Root Mean Square (RMS) value of all deviations of individual spacing lengths from the average spacing should not be more than two percent computed in accordance with TE&CM 431.

10.34 Where the application of the RMS method for determining spacing deviation requirements is not practical due to staking and/or construction or other local factors, the method discussed below is considered acceptable.

10.341 Average of the differences (with signs disregarded) between the individual spacings and average spacings should be within two percent.

10.35 Deviation of the length of longest individual sections from the average spacing should be within ± 3 percent.

10.351 Where terrain or other local factors make it impossible for an individual loading section to meet the ± 3 percent requirements of paragraph 10.35 above with actual cable, an individual loading section may vary as much as -15 percent but only +3 percent from the average spacing. Where this becomes necessary, the short section should be electrically built-out to the average spacing of paragraph 10.32 by means of a building-out capacitor. Step-by-step procedure for computing the amount of building-out capacitance required when this becomes necessary is shown in REA TE&CM 431. It is to be emphasized that this method is to provide staking personnel a tool for dealing successfully with abnormal situations only and is not recommended as a general practice.

10.4 Load Spacing Requirements (H-88)

10.41 As-built plant, including main cable length, lateral cable distance to and from pedestals, pedestal height, pedestal loop-around and all other incidental lengths should meet the following spacing requirements:

10.42 Deviation of the average spacing from the standard spacing should be within ± 2 percent.

10.43 Average of the differences (with signs disregarded) between the individual spacings and average spacings should be within one-half of one percent.

10.44 Deviation of the length of longest individual sections from the average spacing should be within ± 2 percent.

10.441 Where terrain or other local factors make it impossible for an individual loading section to meet the ± 2 percent requirements of paragraph 10.44 above with actual cable, an individual loading section may vary as much as -15 percent but only +2 percent from the average spacing. Where this becomes necessary, the short section should be electrically built-out to the average spacing of paragraph 10.42 by means of a building-out capacitor. Step-by-step procedure for computing the amount of building-out capacitance required when this becomes necessary is shown in REA TE&CM 431. It is to be emphasized that this method is to provide staking personnel a tool for dealing successfully with abnormal situations only and is not recommended as a general practice.

10.5 Subscribers Between Loading Points

10.51 Subscribers on loaded loops should be connected only in the end-section after the last loading coil. Under no circumstances should subscribers be connected between loading coils.

11. CENTRAL OFFICE PAIR BRIDGING

11.1 It is sometimes desirable to bridge party line pairs together at central office locations. When this is necessary, the total bridged tap length of the non-loaded pairs bridged at the central office main frame without BTI's should not exceed 9000 feet. Paragraph 2.3 applies.

11.2 Non-loaded pairs should not be bridged to loaded pairs without BTI's.

11.3 Loaded pairs should not be bridged to loaded pairs without BTI's.

11.4 Refer to TE&CM 428 for detailed application of BTI's.

12. TELEPHONE SET

12.1 Use of telephone sets which are on the current REA List of Materials for all loops regardless of length is recommended.

3. NOISE CONSIDERATIONS

13.1 To minimize noise on loops, the following design guidelines should be applied.

13.11 When establishing routes, maintain a separation from power lines in the area of 500 feet or greater where possible.

13.12 Avoid placing buried telephone plant under power lines where possible. Where jointly buried electric and telephone facilities are provided, restrict the length to one-half mile.

13.13 Use fully shielded cables with shield continuity maintained throughout the cable length and shield grounds made properly.

13.14 Do not use non-shielded aerial type distribution wire for main routes.

13.15 Avoid the use of open wire conductors in joint use arrangements to connect with cables.

13.16 Use ringers which are on the REA List of Materials. Where divided ringers must be used (more than five parties on a line or two-party ANI), assign an equal number of ringers on each side of the line, where practical (see TE&CM 212).

13.17 For maximum noise advantage, connect all ringers bridged if this does not result in semi-selective ringing (see TE&CM 212).

13.18 Where BTI's are used, all ringers on the line must be bridged.

13.19 The preferred type of Automatic Number Identification on two-party lines requires divided ringing and resistance ground at the tip party station during the talking condition. This arrangement is usually satisfactory from a noise consideration in the presence of a moderate power exposure, but may cause objectionable noise on severely exposed lines. The best way to eliminate this problem is to avoid two-party ANI by eliminating two-party service where practicable to do so. Bridged ringing may be used with two-party ANI lines if a special inductor is used for the ground mark instead of a ringer winding. The special inductors should be resorted to only after a noise problem has been determined to exist because of divided ringers (see TE&CM 707).

14. SUBSCRIBER OR STATION CARRIER

14.1 Subscriber carrier equipment is often used to derive all or a portion of the two-wire voice frequency subscriber loop. The wide variety of equipment available ranges from one channel type added to relatively short non-loaded physical loops up to 36 channels or more on two wire pairs over distances of 50 miles or more.

14.2 When subscriber carrier equipment is used, the combined overall loop composed of carrier derived and voice frequency portions should meet all voice frequency transmission objectives (i.e., 8 dB maximum loss at 1000 Hz, etc.).

14.3 For purposes of categorizing to determine if net loss computations are necessary, subscriber carrier will be considered to be in three categories. They are the types where: (a) subscriber terminals are located at the subscribers building (inside or outside mounted); (b) subscribers terminals are located individually or in small groups near the subscriber's building; and (c) subscribers terminals are terminated in large clusters of channels (drops may be short or very long). The following paragraphs are guidelines on the transmission considerations of these types of applications (see Figure 4).

14.31 The first category of subscriber carrier is a type of equipment designed to be mounted inside or very near the subscriber's building. These are often one channel add-on types and have very short length voice drop capability (i.e., 25 ohms). Transmission calculations are not necessary for these types; the net loss of the carrier channel is either factory adjusted or can be manually adjusted to provide low loss. Resistance of the telephone set becomes critical because it predominates in control of the loop current. A higher than normal set resistance or a push button telephone may result in an inadequate loop current even though the loop does not exceed 25 ohms.

14.32 The second category refers primarily to the station carrier variety of equipment. Computations may be necessary to insure that 8 dB maximum loss is met. Thus, a loss must be assigned to the carrier derived portion that takes into account the design net loss plus the manufacturing and field variations. If the carrier portion of the net loss can be maintained at 3 ± 1 dB, then 4 dB is available for the voice drop from the subscriber terminal which should be easily met for one-party service. (NOTE: The net loss of some station carrier is currently as much as 4 ± 2 dB which may require computations as indicated above.)

14.33 The third category refers to higher density types of subscriber carrier equipment that may serve a cluster of about a dozen or more subscribers, or may be used in lieu of a central office to serve several hundred subscribers. There is a wide variety of equipment in this category that ranges from older open wire and cable carrier systems to the more modern pulse code modulation (PCM) subscriber carrier systems. For the most part, the newer equipment is factory adjusted to 2 ± 1 dB loss, leaving 5 dB for the voice drop facility. If the factory adjusted loss is greater than 2 ± 1 dB or cannot be field adjusted to that value, then the voice drop must be shortened accordingly to maintain loops of 8 dB maximum loss.

14.4 The application of subscriber carrier equipment is discussed in REA TE&CM Sections 903, 905, 910, 911 and 951.

15. REMOTE ELECTRONIC SUBSCRIBER LINE SWITCHING SYSTEMS

15.1 Several new remote switching systems are now available for subscriber loops. These systems which can use either voice or carrier derived trunks to interconnect the central office and subscriber terminals use electronic switching techniques to concentrate a large number of loops via a smaller number of trunks. From a purely transmission standpoint, these systems should be treated as follows:

15.11 Where a voice frequency trunk is used, compute the 1000 Hz loss in the portion of the system between the central office and remote switching unit. Use the computation procedure in REA TE&CM 426 to determine the amount of loss. If voice frequency repeaters

are used in the trunk portion of the system, design the repeatered circuit in accordance with REA TE&CM 444 or 446 as applicable. The repeatered trunk portion can be engineered to have a net 1000 Hz loss as low as 2.0 dB by reference to Chart V in Section 446.

15.12 Subscriber loop portion between the remote terminal and the subscriber is engineered separately by using design procedures in this Section which are applicable.

15.13 1000 Hz loss to the farthest subscriber is determined by adding the 1000 Hz loss of the trunk portion in paragraph 15.11 above to the 1000 Hz loss for the subscriber loop portion in paragraph 15.12. The total 1000 Hz loss to the farthest subscriber should not exceed the maximum limit of 8 dB.

15.14 Talking battery for these systems is furnished from the subscriber terminal. Loop extenders, booster battery with long line adapters and voice frequency repeaters discussed previously may also apply.

15.2 Where carrier frequency techniques are used in the portion of the system between the central office and the remote switching unit, use information in paragraph 14.33 for high density subscriber carrier systems to determine the maximum loop limits.

16. WHEN TRANSMISSION COMPUTATIONS NEED BE MADE

16.1 Tables I and II and Charts I, II and III

16.11 Transmission computations are not necessary for the type subscriber loop facilities shown in Tables I and II and Charts I, II and III.

16.2 Open Wire Conductors

16.21 Where loaded cable is extended with open wire conductors, transmission calculations are not necessary if the total dc resistance in the outside plant is within the maximum value in Chart I.

16.3 PABX Trunks

16.31 Compute the 1000 Hz loss using the information in REA TE&CM 426. The maximum loss for the farthest subscriber should not exceed 8 dB at 1000 Hz, including the loss and gain of the following:

- (a) Outside plant, central office to PABX.
- (b) Long line adapter or loop extender loss of 0.4 dB if used.
- (c) Voice frequency repeater gain where used.
- (d) Effective gain of other amplification devices.
- (e) PABX loss of 0.5 dB.
- (f) Outside plant, PABX to farthest station.

16.32 Consideration may be given to using carrier for the trunk portion and perhaps long PABX station loops.

16.4 Subscriber or Station Carrier

16.41 Where carrier is extended with physical plant at the carrier voice frequency drops, loading criteria apply and transmission calculations should be made. Use the computation procedure in REA TEGCM 426 and paragraph 14 above.

16.5 Remote Electronic Subscriber Line Switching Systems

16.51 Where systems of this type are derived entirely on a voice frequency basis or where carrier derived trunks are used extended with voice frequency loops, transmission calculations should be made. Use the procedure of paragraph 15 above and carry out computations in accordance with TEGCM 426.

16.6 For facilities other than those above, compute the 1000 Hz loss using the information in TEGCM 426. Maximum loss for the farthest subscriber for a subscriber loop composed of any type outside plant facilities should not exceed 8 dB maximum at 1000 Hz, including the loss and gain of the following.

- (a) Outside plant
- (b) Long line adapter or loop extender loss of 0.4 dB if used
- (c) Voice frequency repeater gain where used
- (d) Effective gain of other amplification devices

TABLE I

UNIFORM GAUGE 24-D-66 AND 22-D-66 BURIED PLANT¹
FOR MAXIMUM LENGTH SHOWN BELOW
NEW OFFICE OR EXISTING²

Outside Plant Facility	Maximum Circuit Length ¹		Maximum End Section Length KF	Treat Loop as Follows:
	KF	MI.		
24-D-66	24.6	4.6	12.0	48V C.O. NO LIA OR LOOP EXTENDER
22-D-66	38.7	7.3	12.0	500 TYPE TEL SET
24-D-66	32.0	6.1	6.5	48V C.O. NO LIA OR LOOP EXTENDER
22-D-66	50.5	9.6	6.5	500 TYPE TEL SET
24-D-66	56.4	10.7	12.0	LOOP EXTENDER OR 24 OR 48V BOOSTER POWER SUPPLY & LIA
22-D-66	87.8	16.6	12.0	6.5 NET GAIN VFR AT C.O. 500 TYPE TEL SET
24-D-66	60.8	16.6	6.5	LOOP EXTENDER OR 48V BOOSTER POWER SUPPLY & LIA
22-D-66	94.5	17.8	6.5	6.5 DB NET GAIN VFR AT C.O. 500 TYPE TEL SET
24-D-66	71.5	13.5	12.0	LOOP EXTENDER OR 48V BOOSTER POWER SUPPLY & LIA3 & 4
22-D-66	112.7	21.4	12.0	11 DB NET GAIN VFR FIELD MTG. 500 TYPE TEL SET
24-D-66	80.7	15.3	6.5	LOOP EXTENDER OR 48V BOOSTER POWER SUPPLY & LIA3 & 4
22-D-66	126.0	23.9	6.5	11 DB NET GAIN VFR FIELD MTG. 500 TYPE SET

- NOTES:
1. ESSENTIALLY BURIED PLANT CONSTRUCTION. FOR AERIAL CONSTRUCTION REDUCE LENGTH SHOWN BY 12 PERCENT. FOR TYPES OF PLANT WITH BURIED AND AERIAL CONSTRUCTION, THE PLANT IS DEFINED AS ALL BURIED FOR PURPOSES OF SIGNALING IF THE LENGTH OF AERIAL PORTION IS 10 PERCENT OR LESS OF THE TOTAL AND ALL AERIAL IF IT IS MORE THAN 10 PERCENT.
 2. EXISTING OFFICES MODIFIED TO EXTEND THEIR SIGNALING CAPABILITY AS PER PARAGRAPH 4.2 ABOVE.
 3. LOCATED AT ANY POINT IN MIDDLE ELECTRICAL THIRD OF LINE CONVENIENT FOR MOUNTING SEVERAL REPEATER UNITS. POWER FEED CAN BE FROM C.O. BATTERIES & BOOSTER OVER ADDITIONAL CABLE PAIR (SIMPLEX) OR AT REPEATER LOCATION WITH AC TO DC CONVERTER. SET LBO(S) FOR 4500 FEET CBO INCLUDING CABLE END-SECTIONS ADJACENT TO REPEATER.
 4. FOR CMO OFFICES GAIN OF FIELD MOUNTED REPEATER IS SET TO 4.5 DB NET GAIN WITH AN OFFICE MOUNTED REPEATER SET FOR 6.5 DB NET GAIN.

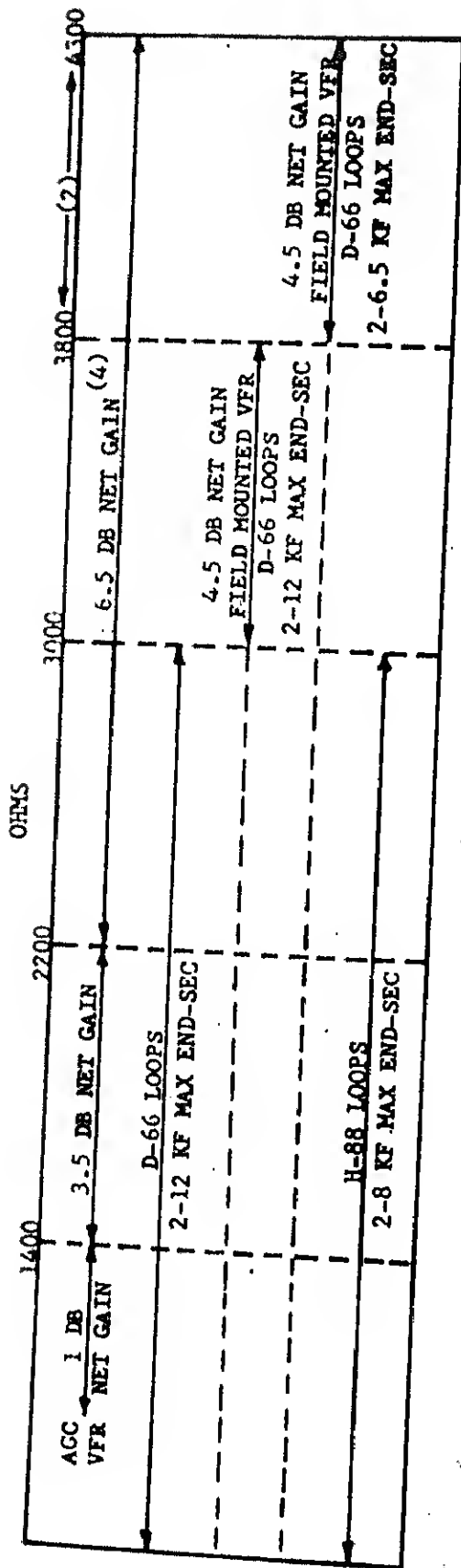
TABLE 11

UNIFORM GAUGE 24-H-88, 22-H-88 and 19-H-88 PLANT
FOR MAXIMUM LENGTH SHOWN BELOW
NEW OFFICE OR EXISTING?

Outside Plant Facility	Maximum Circuit Length, up to	Maximum End Section Length Kt	Treat Loop as Follows:
24-H-88	32.0	6.0	48V C.O. NO LLA OR LOOP EXTENDER
22-H-88	50.0	9.4	500 TYPE TEL SET
24-H-88	58.0	10.9	LOOP EXTENDER OR 48V BOOSTER POWER SUPPLY WITH
22-H-88	89.2	16.9	LLA 500 TEL SET 6.5 DB NET GAIN VFR AT C.O.3

NOTES:

1. ESSENTIALLY BURIED PLANT CONSTRUCTION. FOR AERIAL PLANT CONSTRUCTION REDUCE LENGTH SHOWN BY 12 PERCENT. FOR TYPES OF PLANT WITH BURIED AND AERIAL CONSTRUCTION THE LENGTH IS DEFINED AS ALL BURIED FOR SIGNALING PURPOSES IF THE LENGTH OF AERIAL PORTION IS 10 PERCENT OR LESS OF THE TOTAL AND ALL AERIAL IF IT IS MORE THAN 10 PERCENT. LOAD SPACING MEETS REQUIREMENTS OF PARAGRAPHS 10.2 & 10.3 ABOVE. CABLE CAPACITANCE IS WITHIN $\pm 0.007 \mu F$ FROM AVERAGE $0.083 \mu F$.
2. EXISTING OFFICES MODIFIED TO EXTEND THEIR SIGNALING CAPABILITY AS PER PARAGRAPH 4.2 ABOVE.
3. LOCATED AT C.O. BUILD-OUT LBO TO 5800 FEET TOTAL INCLUDING CABLE END-SECTION ADJACENT TO REPEATER. CABLE PLANT SHOULD HAVE A MINIMUM 18 DB ECHO RETURN LOSS FOR APPLICATION OF REPEATERS. INTERMEDIATE REPEATERS NOT RECOMMENDED BECAUSE OF CUMULATIVE DEGRADATION IN THE AVAILABLE SPEECH BAND.



1. ONLY LOADED CABLE LOOPS TO BE ASSIGNED.
2. END-SECTIONS IN EXCESS OF 6.5 KF AND LESS THAN 12 KF MAY BE DESIGNED IN THIS ZONE ON A CIRCUIT BY CIRCUIT BASIS.
3. FOR AERIAL CABLE REDUCE ALL RESISTANCE LIMITS BY 12 PERCENT.
4. BEYOND 3000 OHMS ADDITIONAL GAIN WILL BE REQUIRED WITH FIELD MOUNTED VOICE FREQUENCY REPEATERS.

CHART II

TRANSMISSION DESIGN FOR BURIED PLANT (3) CMO OPERATION WITH AGC VFR

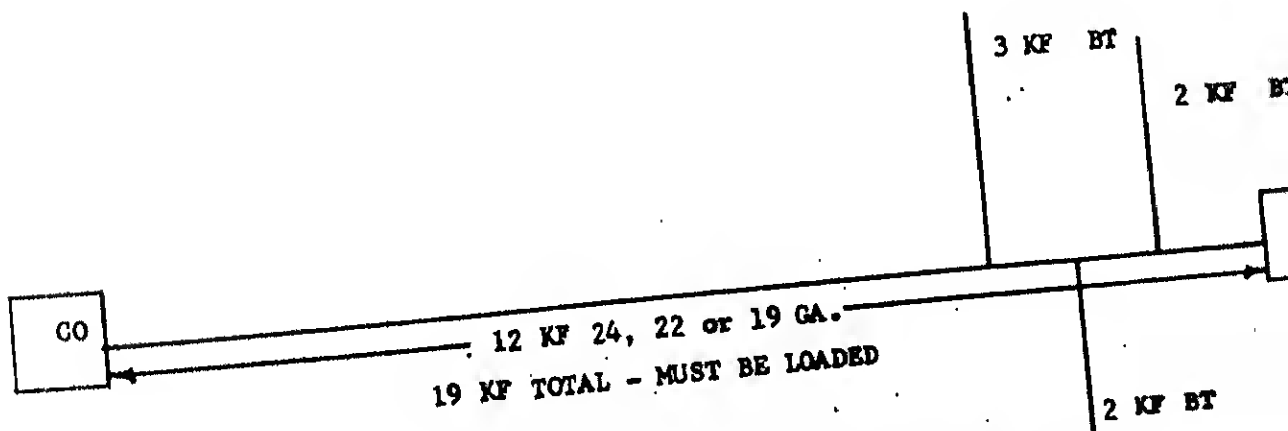
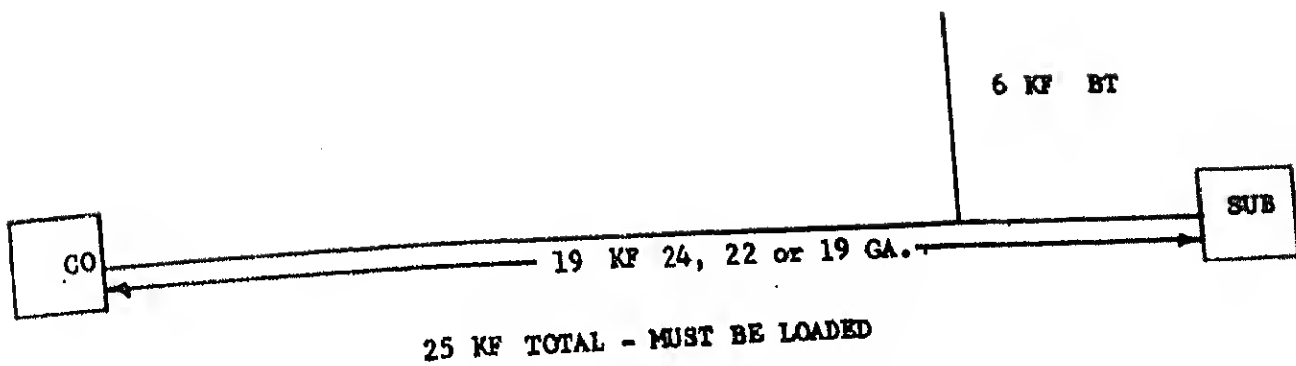
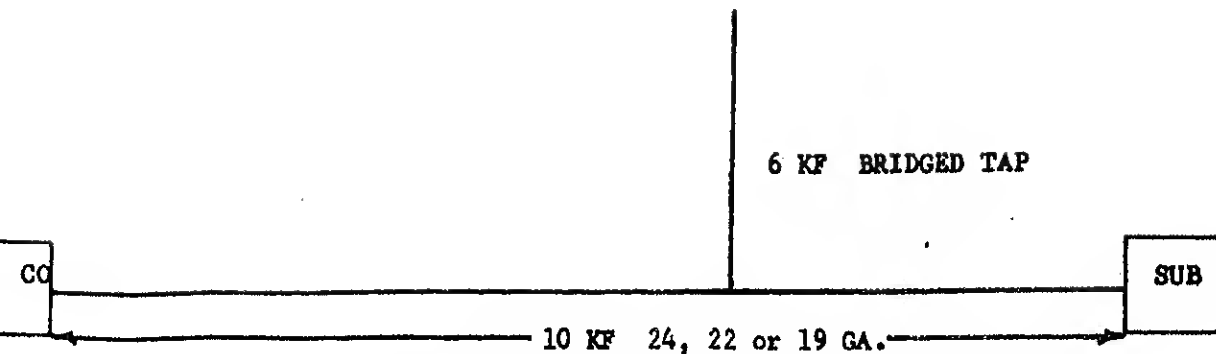
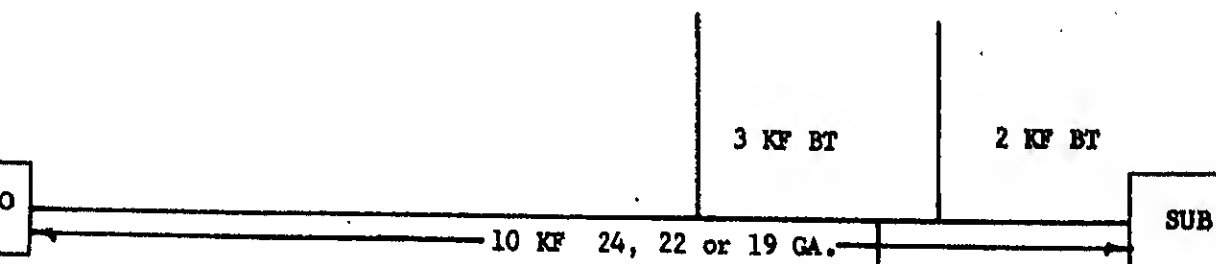


FIGURE 3 - EXAMPLES OF LOOPS WITH BRIDGED TAPS



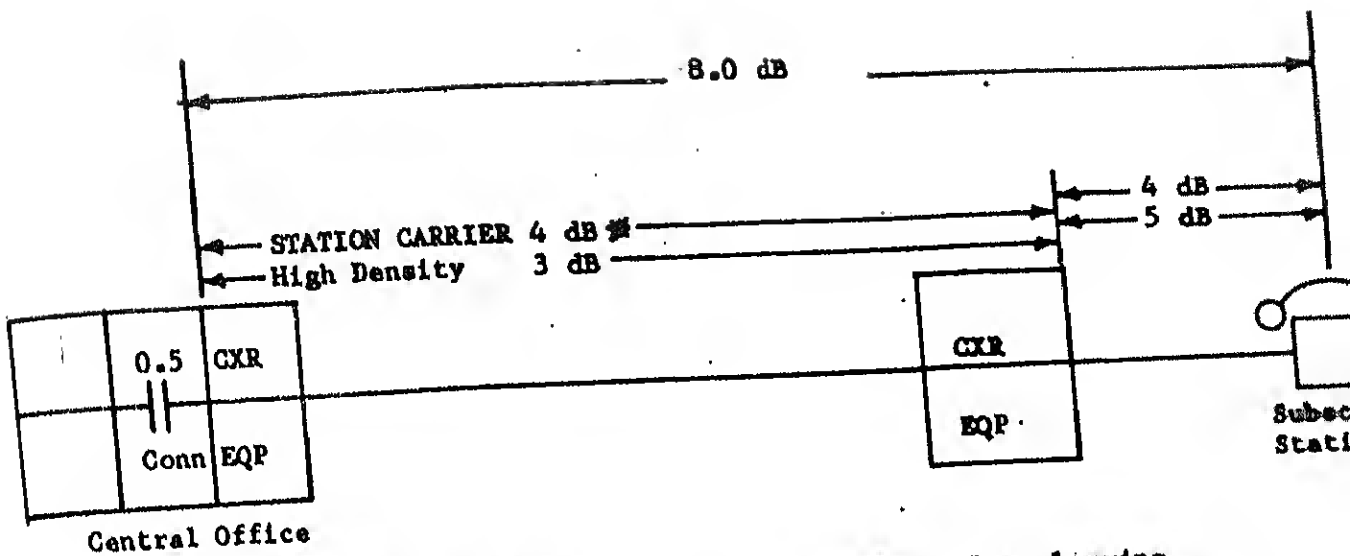
NOTE: 16 KF TOTAL - DOES NOT REQUIRE LOADING



NOTE: 17 KF TOTAL - DOES NOT REQUIRE LOADING BUT
 7 KF BRIDGED TAP - NOT ALLOWED
 BT MUST BE REDUCED BY AT LEAST 1 KF OR
 USE BTI

2 KF BT

FIGURE 3 (Con't.)



NOTE: *Some station carrier can have 6 dB net loss leaving only 2 dB for the voice frequency drop.

FIGURE 4
SUBSCRIBER CARRIER PLUS PHYSICAL LOOP